Employment of Hypersonic Glide Vehicles: Proposed Criteria for Use

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Abstract. Hypersonic Glide Vehicles (HGVs) are a type of reentry vehicle that couples the high speed of ballistic missiles with the maneuverability of aircraft. The HGV has been in development since the 1970s, and its technology falls under Conventional Prompt Global Strike (CPGS) weapons. As noted by James M. Acton, a senior associate in the Nuclear Policy Program at Carnegie Endowment, CPGS is a "missile in search of a mission." With the introduction of any significant new military capability, a doctrine for use—including specifics regarding how, when and where it would be used, as well as tactics, training and procedures—must be clearly defined and understood by policy makers, military commanders, and planners. In this paper, the benefits and limitations of the HGV are presented. Proposed criteria and four scenarios illustrate a possible method for assessing when to use an HGV.

Introduction

Hypersonic Glide Vehicles (HGVs), also known as Boost Glide Vehicles (BGVs), are the next generation of conventional, long-range weapons. They are a type of reentry vehicle that couples the high speed of ballistic missiles with the maneuverability of aircraft.[2] The HGV has been in development since the 1970s, and its technology is one of many considered for Conventional Prompt Global Strike (CPGS) weapons. As noted by James M. Acton, a senior associate in the Nuclear Policy Program at Carnegie Endowment, CPGS is a "missile in search of a mission."[3]

This paper briefly describes the HGV development and its characteristics. Then the author presents and augments criteria from the literature as a possible method for determining conditions for the use of the HGV as a weapon. Four scenarios illustrate possible HGV uses and associated issues.

Background on Hypersonic Glide Vehicles

As a reentry vehicle, an HGV is capable of aerodynamic lift and gliding to change the trajectory from ballistic to non-ballistic, increase its range on reentry into the atmosphere[4], and provide it with the ability to maneuver. These vehicles are referred to as hypersonic because they can travel in the regime of speeds labeled as hypersonic by the National Aeronautics and Space Administration (NASA), i.e., greater than Mach 5 but less than Mach 25.[5] The HGV is considered a glide vehicle because after a rocket accelerates it to a desired speed, the rocket and HGV separate, and then the HGV travels unpowered (glides) to its final destination/target. They

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[2] Harry Kazianis, "The real military game-changer: Hypersonic weapons 101," *Lowy Institute for International Policy*, March 14, 2014, http://www.lowyinterpreter.org/post/2014/03/14/Hypersonic-weapons-101.aspx

[3] James M. Acton, *Silver Bullet? Asking the Right Questions About Conventional Prompt Global Strike* (Washington D.C.: Carnegie Endowment for International Peace, 2013), 9, http://carnegieendowment.org/2013/09/03/silver-bullet-asking-right-questions-about-conventional-prompt-global-strike/gkmp.

[4] Boost-glide vehicle, Answers.com. McGraw-Hill Dictionary of Scientific and Technical Terms, McGraw-Hill Companies, Inc., 2003, http://www.answers.com/topic/boost-glide-vehicle.

[5] Kazianis, "Military game-changer: Hypersonic weapons."

are not powered vehicles and so cannot maintain a level flight at a constant speed and altitude; a glider in steady gliding flight is always descending relative to the air around it, thus exchanging altitude for maintenance of velocity.[6]

Two long-range HGVs have been under development since the early 2000s: the Hypersonic Technology Vehicle (HTV-2) and the Advanced Hypersonic Weapon (AHW). For the HTV-2, the range is 10,000 miles,[7] the cross-range is about 3300 miles,[8] accuracy is a few meters (assuming GPS/INS navigation),[9] and speed is Mach 20-plus.[10] For the AHW, the range is 3500 to 5000 miles[11] (a 2014 flight test is scheduled for 4000 miles[12]), the cross-range is about 1200 to 1700 miles,[13] accuracy is less than 10 meters,[14] and speed is Mach 8.[15] The characteristics are summarized in Table 1.

Table 1. General Characteristics of Hypersonic Glide Vehicles

Hypersonic Glide Vehicle	Range	Cross Range	Accuracy	Speed
Hypersonic Technology Vehicle (HTV)-2	16000 km (10,000 mi)	5300 km (3300 mi)	Few meters	Mach 20-plus
Advanced Hypersonic Weapon (AHW)	5600-8000 km (3500-5000 mi)	1900-2700 km (1200-1700 mi)	< 10 meters	Mach 8

Hypersonic Technology Vehicle (HTV)-2

The vehicle known as HTV-2 was the primary focus of the HGV effort from 2003 until 2012.[16] In 2004, the initial version of the HTV was known as the Common Aero Vehicle (CAV); the

[6] Thomas E. Beach, "TR-4 Model Rocket Technical Report Boost Gliders," *Estes-Cox Corp.*, 2012, http://www2.estesrockets.com/pdf/2266_TR-4_Boost_Gliders.pdf.

[7] Acton, *Silver Bullet?*, 43.

[8] Design dependent, assumes a 3/1 ratio for range to cross-range; Jess Sponable, "Reusable Space Systems: 21st Century Technology Challenges," Presentation, Defense Advanced Research Projects Agency, June 17, 2009, http://nia-cms.nianet.org/getattachment/resources/Education/Continuining-Education/Seminars-and-Colloquia/Seminars-2009/Reusable-Space-Systems,-LaRC,-17-Jun-09.pptx.aspx

[9] National Research Council, *U.S. Conventional Prompt Global Strike Issues for 2008 and Beyond*, (Washington D.C.: National Academies Press, 2008), 7

[10] Guy Norris, "Review Board Sets Up to Probe HTV-2 Loss," *AviationWeek*, August 11, 2011. http://aviationweek.com/awin/review-board-sets-probe-htv-2-loss-0.

[11] Gunnar Arbman and Charles Thornton, "Russia's Tactical Nuclear Weapons Part I: Background and Policy Issues," (FOI-R--1057--SE), *Swedish Defence Research Agency* (November 2003), http://www.foi.se/ReportFiles/foir_1057.pdf.

[12] Kisaq, LLC, Advanced Hypersonic Weapon Flight Test 2 Environmental Assessment, *U.S. Army Space and Missile Defense Command*, (April 2014): 2-6. http://www.ahw-ft2-htt-ea.info/documents/HTT_FT02_PublicDraftEA.pdf.

[13] Design dependent (see Footnote 9 above)

[14] "Advanced Hypersonic Weapon (AHW)," *GlobalSecurity.org*, last modified November 17, 2011, http://www.globalsecurity.org/military/systems/munitions/ahw.htm.

[15] Noah Shachtman, "2,400 Miles in Minutes? No Sweat! Hypersonic Weapon Passes Easy Test," *Wired*, November 27, 2011, http://www.wired.com/2011/11/2400-miles-in-minutes-hypersonic-weapon-passes-easy-test/

[16] Acton, *Silver Bullet?*, 39-41.

program was funded under the National Defense Authorization Act for Fiscal Year (FY) 2004.[17] Two years later, the CAV program was restructured and redesignated as the Hypersonic Technology Vehicle (HTV) because of a Congressional concern that other nations might misinterpret the CAV as a non-conventional launch.[18]

Design flaws were discovered in the HTV in 2007. Its successor—HTV-2—was developed and then flight tested twice in 2010-2011. The HTV-2 successfully separated from its booster in both tests, but the flights were terminated prematurely by the on-board flight-termination system. Though the main objective of reaching the target was not met, the tests were not considered total failures because valuable flight test data was collected up to the point of flight termination. However, because of those two early flight terminations, the HTV-2 program was restructured to a "risk reduction/technology maturation program" and funding shifted to the AHW program.[19]

Advanced Hypersonic Weapon (AHW)

The AHW, now the main focus of U.S. HGV development efforts, is a direct descendant and a scaled-up version of a previously tested system, the Sandia Winged Energetic Reentry Vehicle Experiment (SWERVE),[20] which was successfully tested three times between 1979 and 1985.[21] Funding for the AHW increased from $1.5 million in 2006, when it was considered as a risk mitigation project, to approximately $42 million in 2013,[22] when it became the primary focus of U.S. HGV efforts. A successful test flight was launched in November, 2011, by a Strategic Targets System (STARS) booster from Pacific Missile Range Facility in Hawaii; it impacted on the Reagan Test Site in Kwajalein Atoll about 2500 miles away. A second AHW test, scheduled to take place in FY2014, will launch from the Kodiak Launch Complex in Alaska with an impact point at the Reagan Test Site, a distance of approximately 4000 miles.

Trajectory Differences Between Ballistic Weapons and Hypersonic Glide Vehicles

The trajectory of a ballistic weapon is fairly predictable after its powered phase, because its movement is controlled by the laws of classic physics. An HGV, in contrast, is aerodynamically guided and can maneuver almost continually during its gliding phase, though any maneuvering reduces its range. Thus, while a ballistic weapon's point of impact can easily be calculated after its powered phase, an HGV's impact can be anywhere within its range. Figure 1 provides a comparison of the possible trajectories for a ballistic weapon and an HGV.

[17] Amy F. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles," *Congressional Research Service*, 7-5700, R41464, April 26, 2013, 20, http://www.hsdl.org/?view&did=735886.
[18] Ibid., 21.
[19] Acton, *Silver Bullet?*, 40.
[20] Ibid., 39-40, 47.
[21] Kenneth W. Iliff and Mary F. Shafer, "A Comparison of Hypersonic Vehicle Flight and Prediction Results," *NASA Technical Memorandum* (#104313) (1995): 7, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19960003513.pdf.
[22] Woolf, "Conventional Prompt Global Strike and Long-Range," 19.

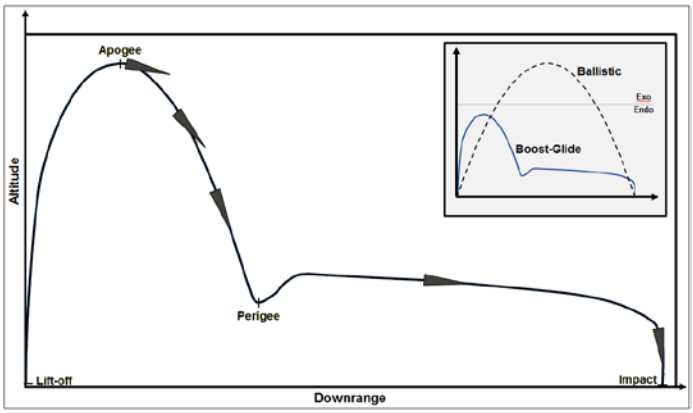

***Figure 1. Comparison of Trajectories for Ballistic Weapon and HGV*[23].**

HGV Benefits and Limitations as Military Weapon

Benefits

An HGV's primary benefit is speed. Traveling at many times the speed of sound allows an HGV to reach any target, within its range, in under an hour. Its velocity also makes it extremely difficult to intercept, which greatly increases the chances of penetration of air defenses, even when an adversary is able to detect the launch and/or track it during flight. An HGV's speed also compresses an adversary's reaction time, assuming the launch is detected.

Another HGV benefit is maneuverability. Studies suggest that an HGV's unpredictable maneuvering, like its speed, would help it penetrate advanced air defenses.[24] Even the U.S. anti-ballistic missile defense system, arguably the most advanced in the world given its overall success rate (80% as of October 2013[25]), has never been shown to hit a maneuvering target. A relatively safe conclusion, therefore, is that no nation at present could destroy a maneuvering HGV and likely would not be able to in the near future.

Limitations

The HGV has three primary limitations: technology, numbers, and cost.

The major technological issue is material development related to extreme heat. At its travel speed, an HGV is subjected to extremely high temperatures, e.g., about 1930°C (3500°F) during the two HGV-2 test flights.[26] To mitigate temperature effects, customized, high technology, expensive materials are required, which greatly increase cost. Assuming that the HGV can be developed to sufficiently withstand the heat throughout its attack path, other technical issues that must be considered include range, payload, accuracy, and guidance systems.

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[23] Debra G. Wymer, "Advanced Hypersonic Weapon Flight Test Overview to the Space & Missile Defense Conference," *Presentation at the Space & Missile Defense Conference*, Huntsville, AL, August 2012, http://www.smdc.army.mil/TechCenter/2013/PowerPoint/FINALAHWBrieftoSMD Conference081312.pptx

[24] National Research Council, *U.S. Conventional Prompt Global Strike Issues for 2008*.

[25] "Ballistic Missile Defense Intercept Flight Test Record," *Missile Defense Agency Fact Sheet*, October 4, 2013, http://www.mda.mil/global/documents/pdf/testrecord.pdf.

[26] Tariq Malik, "Death of DARPA's Superfast Hypersonic Glider Explained," *Space.com*, April 23, 2013, http://www.space.com/15388-darpa-hypersonic-glider-demise-explained.html..

The small number of expected HGVs and the costs are also limitations. According to Acton, U.S. officials consider that the HGV and CPGS in general, will be a niche capability,[27] and so the deployed numbers will remain relatively low (i.e., tens of units, rather than hundreds). Two reasons explain these expectations. The first is strategic stability. Russia has expressed concerns about the CPGS program, including a fear that it would provide the United States with the capability to launch a disarming first strike without crossing the nuclear threshold.[28,29] The second reason is cost. According to the Congressional Budget Office (CBO), AHW and HTV-2 are predicted to cost about $26 million and $36 million (in 2006 dollars) per unit respectively, not including development costs.[30]

Proposed Criteria regarding HGV Targets

Generally, when the use of the HGV is considered, the discussion focuses on limited scenarios or missions such as counterterrorism, pre-emptive strikes, or retaliatory strikes. To broaden the focus, Amy Woolf of the Congressional Research Service (CRS) has proposed basic criteria in the form of questions about weapon applicability that could be asked with respect to any scenario or mission instead of limiting the discussion to the scenarios noted above.[31] In concert with this approach, Woolf's questions are presented below along with two additional questions: one proposed solely by the author and another proposed by the author in collaboration with James Acton.

*Question 1 (Woolf): Do we need **speed (promptness)**? Why do we have to shoot a target so quickly? What's the rush?*

One reason cited frequently regarding the need for HGV development is that an HGV can reach any target in less than an hour if the target is within an HGV's range. This criterion specifically questions the necessity for such speed. For example, is speed necessary? Is there a mobile target that will be temporarily stopped (e.g., a mobile missile preparing to launch)? Is there a terrorist target at a certain location for a limited period of time? Is it necessary to eliminate an enemy's offensive enablers before the enemy orders an attack against radars or C2 centers or before the enemy attacks assets to degrade U.S. warfighting abilities (e.g., anti-satellite weaponry)? Are there other reasons why the United States would require the speed of an HGV instead of using an alternate capability?

*Question 2 (Woolf): Does the attack need to be a **surprise**? Why? What happens if the enemy knows the attack is coming? Can they react in time?*

Some potential HGV targets must be attacked with as little warning as possible because of the potential for the target to be moved or launched (if it is a weapon). This possibility could be a concern with nations that can detect launches or track missiles in flight, or when the United States believes the enemy may be warned of an incoming attack in time to move the target. In considering this criterion, the analysts would question whether the element of surprise would

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[27] Acton, *Silver Bullet?*, 49.
[28] Woolf, "Conventional Prompt Global Strike and Long-Range," 29.
[29] The Russians will still have a 2nd strike capability via their Submarine Launched Ballistic Missiles (SLBMs). See: Oscar Rickett, "We Asked a Military Expert How to Invade and Conquer Russia," *Vice.com*, March 4, 2014, http://www.vice.com/en_uk/read/we-asked-a-military-expert-how-to-invade-and-conquer-russia.
[30] Congressional Budget Office, "Alternatives for Long-Range Ground-Attack Systems," March 2006, xv, http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/71xx/doc7112/03-31-strikeforce.pdf
[31] Amy Woolf, pers.comm.

mean an adversary would not have time to move its potential assets or, if the target has an offensive capability, to use the weapon before being destroyed.

*Question 3 (Olguin): Do we have the necessary **enabling capabilities** to support the particular attack? Do we need Command and Control? Intelligence, Surveillance, and Reconnaissance (ISR)? Battle damage assessment?*

Enabling any attack requires target detection, accurate target location information, appropriate weapon selection (depending on the goal), and battle damage assessment. Decisions regarding the use of a particular weapon are based on such variables. Target detection and accurate locations (including altitude, weather, lighting, and surrounding structures) are crucial.

The use of long-range missiles to deliver conventional weapons accurately enough to damage targets requires information that is more detailed than that needed for nuclear weapons or for conventional weapons delivered by aircraft or short-range missiles. The primary issues are related to the following: (1) Command and Control (C2) that reserves decisions to the National Command Authority, while delivering information to the weapon system quickly for a short overall execution time; (2) the provision of the information necessary for accurate weapon delivery to a specified aimpoint; (3) the accurate location of aimpoints; and (4) target detection.[32]

What type of enabling capabilities would be required when deciding to attack a particular target? What kinds of C2 capabilities are available? Will the decision to attack be made at the regional/local level, or must it come from the President? Who has the final say to launch the attack and will he or she be available when needed? Will ISR assets/capabilities be in place, and available to make the attack possible? What type of damage assessment is required and how will it be accomplished (local human assets, satellite imagery, aerial photos etc.)?

*Question 4 (Woolf): Are there **alternative means** to attack the target?*

Four primary areas would affect whether an HGV or an alternative would be used for an attack: (1) target type (soft target, mobile target, hard and deeply buried target, etc.), (2) penetration of enemy airspace, (3) range, and (4) cost. When choosing to attack a target, the U.S. military must select the right tool for the job. Depending on final technical specifications, an HGV may—or may not—be able to follow a moving target, have enough energy to destroy the target (e.g., a hardened target), result in acceptable collateral damage, given the circumstances, or have the ability to penetrate the enemy's airspace because of air defenses. Another factor that must be taken into account is target location. If the target is too far inland or too far away from certain U.S. capabilities, an alternate attack mode must be chosen. And, as stated earlier, HGVs are likely to be niche weapons with a high unit procurement cost.[33] This expense is expected to vastly limit their use, i.e., only for scenarios that require an HGV's specific capabilities.

Alternative means of attacking a target could include drones, bombers, short-range systems, or Special Forces:

- **Drones.** Is there a drone in the area? Drones can look and loiter. Does a drone's payload have enough firepower to take the target out?

[32] National Research Council, *U.S. Conventional Prompt Global Strike Issues for 2008*, 51.
[33] Acton, *Silver Bullet?*, 49.

One of the most popular counterterrorism attack systems are Unmanned Aerial Vehicles (UAVs), commonly called drones. Since the war in Afghanistan started in 2001, drones have been heavily employed by the U.S. military, mainly for counterterrorism. Drones have the advantage of being able to loiter and look around the target's area. When a drone is used to attack a target, it can use onboard sensors and cameras for damage assessment and possibly launch a follow-on attack if the first one was not successful. Is there a drone nearby that could be used to attack the target? Would it be preferable to use a drone, whose attack can be seen by its operator, or use an HGV from up to thousands of miles away? Would the drone's firepower be sufficient to destroy the target, or would a larger weapon be needed to do the job?

- **Bombers.** Is a bomber close enough to be timely? Can it penetrate airspace (is a suppression package needed)? Can the attack wait until the bomber gets there?

  Bombers can carry powerful bombs, and with aerial refueling, they have virtually unlimited range. However, a bomber must fly over the target to drop its munitions and also is often too far away to be used at a moment's notice. If it is a time-sensitive target, it may take too long to get a bomber from as far away as Missouri to the target in time. Will the bomber be able to penetrate the airspace where the target is located or would a suppression package be needed if a bomber is chosen? Countries with some minor air defense capability may be able to shoot down a B-52, but it is more difficult to shoot down a B-1 or B-2 bomber.

- **Short-Range Systems.** Forces in the area? Can we use shorter range systems such as cruise missiles or short range missiles?

  Does the United States have shorter range weapons such as Tomahawk cruise missiles or ATacMS in the area? Are they accurate enough to destroy the targets?

- **Special Forces.** Can we use Special Forces or other boots on the ground?

  The United States has multiple military units trained for high risk missions, such as the Navy SEALs, which can be sent in to destroy targets. Typically, putting "boots on the ground" is a last resort for the United States because of the high risk of casualties.

*Question 5 (Olguin/Acton): What **political enabling capabilities** are necessary? Is there time to produce an assessment and enable the decision? What are the repercussions (political?) of the attack?*

If an HGV is considered a niche weapon, its use would likely be approved by Presidential authorization only.[34,35] Thus, this question concerns the issues, especially political concerns that the President would need to consider before ordering the launch of an HGV. For example, would a majority of the public support the attack? Will launching the attack be the opening salvo of a larger conflict? Because of its speed, will the shorter flight time of an HGV give a President more time to make a decision?

[34] National Research Council, *U.S. Conventional Prompt Global Strike Issues, 65*.

[35] For a larger campaign or full scale war, Presidential authorization would likely be delegated to a local combatant commander.

Four Potential Scenarios

This section provides four common attack scenarios to illustrate a method of determining whether to use an HGV or an alternate weapon. For every scenario, a brief response to each question posed above is presented. These responses are a simplified version of what would likely be a lengthy discussion regarding HGV use in an attack scenario and are presented only as examples.

Scenario 1: Terrorism/Counterterrorism (e.g., Bin Laden raid, Tora Bora, Afghanistan Cruise missile attack)

Terrorism is typically the first mission that comes to mind when talking about potential CPGS and HGV usage scenarios. According to James Acton, terrorism was the easy thing to say publically, but not the most important mission for CPGS.[36] One typical terrorist scenario might be a meeting of several terrorist leaders (or the knowledge of where a high value leader will be), with the timing and location unknown until the last minute. Would this scenario be a good candidate for using HGVs?

1. Is speed (promptness) required?

In a scenario in which the United States learns the location of a high-value terrorist or a meeting of terrorist leaders, speed may be required for various reasons. First, if the location and time are unknown until the target is in place, then the United States would want the attack to occur as soon as soon as possible after the information becomes known. Terrorist meetings would be only as long as necessary because terrorists understand they are actively pursued and any gathering would be considered a target. Before an attack could be launched and assuming a relatively short meeting (an hour or less), the United States would need time to plot the location, verify the intelligence, assess the target, make the decision to attack, and provide enough time for commander authorization. The speed of an HGV potentially allows more time for the preliminary actions while still being able to attack the intended target before the meeting ended. In this scenario, weapon speed would be an advantage.

2. Does the attack need to be a surprise?

A surprise attack is necessary with regard to targeting a terrorist meeting. HGVs would be a good fit for this situation because few nations can detect an HGV launch and, therefore, would be unable to warn any terrorist group with which they are aligned of the pending attack, thus increasing the potential for surprise. If the attack is not a surprise, the terrorist(s) may move or cancel the meeting to thwart the attack.

3. Are the necessary enabling capabilities to support the attack available?

Where there is a large U.S. military presence, such as the Middle East or Afghanistan, enabling capabilities may already be in place or located nearby. In other parts of the globe, the required enabling capabilities may not be available. The answer to this question may be the deciding factor to which weapon to utilize.

4. Does the United States have means other than an HGV to attack the target?

Similar to the response to Question 3, the United States will likely have an alternative means to attack the target if it is located in a region with a large U.S. military presence.

[36] James M. Acton, pers. comm.

- **Drones.** The U.S. military operates drones in many parts of the world; it is likely a drone would be near the target site. If the drone has sufficient firepower to achieve the goal (e.g., destroy the target), a drone would be preferable to an HGV because it can loiter in the area, gather intelligence, and possibly also assess battle damage.
- **Bombers.** Unless bombers are positioned nearby, they likely are not an option for attacking a time-critical target. On the other hand, terrorist groups tend to have a large presence in lawless areas or areas with little to no government control, and so terrorist targets are not likely to be located in an area with a heavily defended airspace. Therefore, it may be possible to position the bomber near the target, if it were chosen.
- **Short Range.** If short-range systems are in the area, their use would be preferable to using an HGV because they are likely to be much cheaper and already have enabling capabilities located nearby.
- **Special Forces.** Unless the target is extremely valuable, Special Forces or similar forces are not likely to be used because of the high risk of casualties. Osama bin Laden is the prime example of an extremely valuable target; the United States may have sent Special Forces to ensure proof of bin Laden's capture or death since an air strike would have destroyed that evidence.

5. What political enabling capabilities are needed?

The American public historically has strongly supported an attack against terrorists when located, as have other nations. Political fallout would occur only if the attack causes widespread collateral damage, kills many civilians, or is a large and secretive operation (the bin Laden raid).

As seen in the bin Laden raid, violating another nation's borders/sovereignty is very politically sensitive. The United States has repeatedly crossed into other nations' territories (on the ground or in the air) to attack terrorist targets (Pakistan, Afghanistan, Yemen, Somalia, etc.). These actions have had the effect of straining relationships with some of these countries and also negatively influencing the perception of the United States by those nations' citizens. Attacking terrorists within these nations' borders through the air (drones, cruise missiles, etc.) appears to have fewer political repercussions than putting U.S. boots on the ground. The United States has historically chosen to accept these consequences in order to destroy the target, because these nations typically are either not close allies, are adversaries, or the political fallout is expected to be minimal.

*Conclusion***:** HGVs are not expected to be used against terrorist targets, because alternative means (drones, short-range systems) are generally available in this scenario. Also, if the target is moving (such as a vehicle), HGVs are not likely to be able to track and destroy it.

Scenario 2: Rogue nation threatens to use Weapons of Mass Destruction (WMD) against the United States (either a plan to attack U.S. WMD or U.S. C2)

In this scenario, a rogue nation (e.g., North Korea or Iran) is threatening to use WMD against the United States or the United States believes that WMD use is imminent.[37,38] In response, the United States decides to strike preemptively. The attack options are to either attack the WMD

[37] Woolf, "Conventional Prompt Global Strike and Long-Range," 65.
[38] Acton, *Silver Bullet?*, 26.

directly (given a known location) or choose to render the country's leadership or C2 powerless to launch the attack.

1. Is speed (promptness) required?

If the United States believed that a WMD launch were imminent, an attack would be required as quickly as possible so the rogue nation would be unable to launch its weapon. If the United States needs to locate the target, the speed of an HGV also potentially allows more time for target location and the decision-making process. In this scenario, weapon speed would be an advantage.

2. Does the attack need to be a surprise?

Preemption of a rogue nation's launch must be a surprise. Without surprise, the WMD launch could either be hastened or moved. If the attack in this scenario were against the rogue nation's leadership, the attack must be a surprise to prevent its leadership from dispersing or hiding.

3. Are the necessary enabling capabilities to support the attack available?

At present, North Korea or other nations in the Middle East are considered rogue nations. The United States has a heavy presence in South Korea and the Middle East, so the enabling capabilities currently are near the likely targets.

4. Does the United States have means other than an HGV to attack the target?

Similar to the response to Question 3, the United States will likely have an alternative means to attack the target if it is located in an area with a large U.S. military presence.

- **Drones.** Most, if not all, countries that possess WMDs have operational air defense systems. Drones are usually highly susceptible to being shot down and so would likely not be a viable alternative to an HGV.[39]
- **Bomber.** A non-stealth bomber (e.g., B-52) would be susceptible to the same air defense systems as a drone unless defense suppression operations were also conducted. The problem is that the element of surprise would be lost unless the suppression operations and the actual attack occurred in quick succession. Also there would be the need to confirm a clear path for the bomber or risk having it shot down. The B-2 (stealth) bomber fleet, stationed in Missouri, would likely be too far for a timely operation in this time-critical scenario.
- **Short Range.** Depending on target location, short-range systems might be preferable to an HGV. A cruise missile can be an attractive alternative if the target location is known and because it is harder to detect given its low flying altitude. On the other hand, short-range systems may be too far away to be effective.
- **Special Forces.** It is possible, though very unlikely, that Special Forces would be used in this scenario if the evidence was indisputable and there was no other way to reach the target in time. Because using Special Forces would be extremely risky, with a high potential for casualties, and the target is likely well defended/protected, their use is not likely.

[39] A. Rafay, comment on Abdul Q. Khan, "U.S. drone can be shot down by Hamza missile: Dr. A. Q. Kahn," Pakistan Defence (Forum), June 7, 2012, http://defence.pk/threads/us-drone-can-be-shot-down-with-hamza-missile-dr-aq-khan.185526/

5. What political enabling capabilities are needed?

Nearly indisputable evidence of an imminent WMD launch would likely be required before the American public would permit a U.S. attack for fear of getting entangled in a new conflict. Given relatively recent history—such as the 1998 cruise missile attack on the Al-Shifa pharmaceutical factory in Somalia thought to be producing chemical weapons[40] or the United Nation's inability to find WMD's prior to the 2003 Iraq war[41]—and the current political landscape, political enablement would likely not be available now or in the near future. However, these conditions may be different when HGVs are fielded in the early to mid-2020s.[42] According to General Michael Hayden, former director of the Central Intelligence Agency (CIA), the CPGS mission will "require very convincing intelligence before any attacks occur."[43]

*Conclusion***:** The potential to use HGVs depends highly on the details of the situation and also if alternatives such as short-range systems or Special Forces are more attractive. Political repercussions would also have to be weighed in any decision to use HGVs against rogue nations, given recent history.

Scenario 3: Anti-Access/Area Denial (A2/AD) Capabilities (nations possessing them now or in the future)

Anti-access and area denial (A2/AD) are modern terms referring to war-fighting strategies intended to prevent an opponent from operating military forces near or in a contested region.[44] Examples of A2/AD systems range from past war systems, such as trenches and land mines, to modern capabilities such as anti-ship or cruise missiles designed to keep a fleet far from a country's coast.

In this scenario, an attack on A2/AD capabilities would be a preemptive strike from afar (out of the range of the target nation's A2/AD systems) with the goal of subduing the enemy's defenses. Attacking an enemy's A2/AD capabilities would likely be the leading edge of a much larger attack and also would signal involvement in a larger conflict. Many nations, including China, Russia, Syria, Iran, North Korea, Pakistan, and others, have or will likely have A2/AD systems in the near future, as well as a reasonably high probability of military conflict with the United States.

1. Is speed (promptness) required?

Attacking an enemy's A2/AD capabilities quickly is necessary so the enemy does not have time to react to the attack. Slower systems, such as cruise missiles, could be detected well before reaching the target, giving the enemy a chance to either launch its attack/counterattack or try to destroy the incoming missiles. An HGV's speed would be valuable should an enemy possess sophisticated air defenses; interception of an HGV attack would be nearly impossible, even if

[40] Michael Barletta, "Chemical Weapons In the Sudan: Allegations and Evidence," *The Nonproliferation Review* 6.1 (Fall 1998): 115-136, http://cns.miis.edu/npr/pdfs/barlet61.pdf.
[41] Walter Pincus and R. Jeffrey Smith, "Official's Key Report On Iraq Is Faulted," *Washington Post*, February 9, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/02/08/AR2007020802387.html.
[42] Acton, *Silver Bullet?*, 50.
[43] CPGS and Long-Range Ballistic Missiles, p. 4
[44] Sam J. Tangredi, "A2/AD and Wars of Necessity," The National Interest (blog), December 8, 2013, http://nationalinterest.org/commentary/a2-ad-wars-necessity-9524.

detected.[45] Assuming detection, the enemy would have less than 30 minutes to assess the incoming attack and respond, which can be a time-consuming process in a military system with a multi-layered chain of command.

2. Does the attack need to be a surprise?

A surprise attack is valuable especially if the situation is escalating and the conflict has not yet begun. A surprise attack could be the leading edge of a larger attack. Without the surprise, the enemy could launch its systems before being hit or, when possible, move them. If the conflict were already well under way, the enemy would likely assume its A2/AD capability would be targeted and respond accordingly.

3. Are the necessary enabling capabilities to support the attack available?

An effective A2/AD system would likely push the necessary enabling capabilities hundreds of miles offshore or away from the engagement zone, thus keeping the enabling capabilities from being available for the initial attack.

4. Does the United States have means other than an HGV to attack the target?

An A2/AD system by definition is meant to keep enemies at a distance. Area penetration may be difficult if the adversary's A2/AD capabilities keep U.S. weaponry farther out than its range.

- **Drones.** Even assuming a drone is stationed nearby, it would have difficulty penetrating the airspace around an A2/AD target; also, it likely would not have enough firepower to sufficiently destroy the target. While the loitering of a drone is an advantage for a terrorist target, it is a disadvantage against an enemy with sophisticated air defenses.
- **Bombers.** Adversaries with A2/AD systems likely have robust air defense systems, either as part of the A2/AD capabilities or as a separate system. These conditions make penetration by plane difficult. To get a bomber close enough, the United States would have to destroy air defenses on its path and around the target. A bomber could also use standoff weapons, such as cruise missiles, to stay out of air defense range, but the range of such weapons may not be sufficient to reach the intended target.
- **Short Range.** These systems are likely not an option because A2/AD systems would keep U.S. forces out of range, at least at the beginning of a conflict.
- **Special Forces.** Special Forces or similar forces are not likely to be used because of the high risk of casualties. Also, in recent U.S. wars and conflicts, a heavy bombing campaign has preceded putting large numbers of boots on the ground.

5. What political enabling capabilities are needed?

For political enablement to launch an attack that would likely lead to a war, the target nation has to have harmed the United States, its interests, or its people sufficiently to necessitate a war. A mutual defense agreement may not be enough to get the public's approval because of American exhaustion after over 10 years of continuous war.

[45] Aaron Mehta, "USAF Sees Speed as Part of the A2/AD Solution," AirForceTimes.com, September 19, 2013, http://www.airforcetimes.com/article/20130919/NEWS04/309190023/USAF-Sees-Speed-Part-A2-AD-Solution.

*Conclusion***:** HGVs have a high likelihood to be used against A2/AD targets because in many places, other weapon systems cannot be used without significant risk of loss of life or risk of losing the element of surprise.

Scenario 4: Anti-Satellite (ASAT) Weaponry

Anti-Satellite (ASAT) weapons are designed to disable or destroy satellites, typically for military purposes. The United States relies heavily on satellites to enable its warfighting capabilities; they are attractive targets for an enemy who wants to degrade U.S. ability to conduct wars. The United States,[46] China,[47] Russia,[48] India,[49] and Israel[50] are known to have attempted to develop or acquire an ASAT system. In this scenario, HGVs would be used against ASATs either as a preemptive strike to prevent an enemy from destroying a U.S. satellite or as a retaliatory strike after an enemy has already destroyed a satellite and to prevent the adversary from damaging or destroying more satellites.

1. Is speed (promptness) required?

In both preemptive and a retaliatory strike scenarios, speed would be required. If the attack is a preventive attack, speed is necessary to destroy as many enemy ASAT assets as possible before they can be utilized. Should an enemy detect the launch of the HGV, it has 30 minutes or less to activate, target, and launch its ASAT systems. If the HGV attack is retaliatory, speed is necessary to destroy ASAT systems that have not yet been launched to prevent further ASAT attacks. For countries such as China that likely have—or will have—located its ASAT weapons deep within its borders, an HGV would be the best method. Alternate weapons, such as cruise missiles, would take hours to get there, giving the target nation time to launch its weapons.[51]

2. Does the attack need to be a surprise?

This scenario requires a surprise attack, especially given a preemptive strike. In an escalating situation in which the United States believes war cannot be averted, a surprise preemptive strike could be launched to ensure the enemy cannot destroy critical U.S. satellites. Without the element of surprise, the enemy could decide to launch or move/reposition its ASAT weapons before the United States can destroy them.

3. Are the necessary enabling capabilities to support the attack available?

In an ASAT attack, the availability of enabling capabilities will depend on target location. For nations with a large landmass, such as Russia and China, the ASAT assets would be positioned far inside their borders, so local enabling capabilities will likely be too far to support alternative means of attacks.

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[46] "US missile hits 'toxic satellite,'" BBC News, February 21, 2008, http://news.bbc.co.uk/2/hi/science/nature/7254540.stm

[47] Marc Kaufman and Dafna Linzer, "China Criticized for Anti-Satellite Missile Test," Washington Post, January 19, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/01/18/AR2007011801029.html

[48] Michail Fomichev, "Russian officer says developing new weapon for space defense," RIA Novosti, May 15, 2010, http://en.ria.ru/russia/20100515/159029349.html.

[49] Peter J. Brown, "India targets China's satellites," Asia Times, January 22, 2010, http://www.atimes.com/atimes/South_Asia/LA22Df01.html

[50] Barbara Opall-Rome, "Arrow-3 Could Be Adapted for Anti-Satellite Role," *Space News International*, 20 no. 44 (2009): 16.

[51] Phillip C. Saunders and Charles D. Lutes, "China's ASAT Test Motivations and Implications," *Joint Force Quarterly* 46 no. 3 (2007): 39-45.

4. Does the United States have means other than an HGV to attack the target?

When considering an attack of ASAT capabilities in Russia and China, range is a very important factor because the ASATs are likely to be located far inland. Alternative means of attacking an ASAT target may not be feasible, as described below.

- **Drones.** Drones would probably have difficulty penetrating an enemy's ASAT weapon airspace, and they may not have enough firepower onboard to incapacitate or destroy the target. For Chinese or Russian targets, drones likely will not have the range necessary.
- **Bombers.** An enemy with robust air defenses and ASAT capabilities will likely keep bombers out of its airspace, so bombers would not be effective. Weapon range may be an issue for standoff weapons, especially if the ASAT weapons are located deep within a country's boundaries.
- **Short Range.** Short-range systems may be an option against geographically small nations but would not have the necessary range against countries such as China or Russia that could deploy ASAT weapons deep within their borders.
- **Special Forces.** Special Forces or similar forces are not likely to be used, at least until the risk of loss of life is reduced. In the past, the United States has preceded large-scale deployment of ground forces with a heavy bombing campaign.

5. What political enabling capabilities are needed?

Similar to the A2/AD scenario, political enablement will only occur if the target nation has harmed the United States, its interests, or its people sufficiently to necessitate a war. A mutual defense agreement may not be enough to gain approval from the public.

*Conclusion***:** An HGV is likely to be used against ASAT targets. It may be the only means to attack in many cases, especially when outside the range of a cruise missile or shorter range systems. HGV use would also benefit when air defense penetration is difficult or not assured.

Summary

HGVs are the next generation of conventional, long-range weapons. Under development since the 1970s, advances are currently being pursued under two separate programs: HTV and AHW. Since late 2012, the AHW has been the main focus of U.S. HGV development efforts, with HTV-2 restructured into a risk reduction and technology maturation program.

HGVs are different from current long-range conventional weapons because they combine the speed of ballistic missiles with the maneuverability of aircraft, which gives them unparalleled speed, agility, and range. These combined traits greatly increase the likelihood of an HGV penetrating enemy air defenses. Limitations of HGVs include technological issues (materials, range, payload, accuracy, and guidance), small production numbers (tens of units), and cost ($26-$36 million per unit in 2006 dollars, not including development costs).

Five criteria were considered in this paper as a method of assessing whether an attack scenario would be a good candidate for the use of an HGV. The criteria were applied to four common scenarios. As seen in Table 2, HGV use would be likely in an attack against A2/AD capabilities or ASAT weapons, given its capabilities and the undesirability of other options. Use of an HGV against rogue nations would depend on scenario specifics; an HGV would likely not be used to

attack a terrorist target. Based on these examples, the proposed methodology can provide guidance regarding appropriate use of an HGV.

Table 2. Summary of Responses per Example Scenarios

Criteria	Scenario			
	Terrorism/ Counterterrorism	**Rogue Nations**	**A2/AD Capabilities**	**Anti-Satellite Weaponry**
Speed necessary?	Yes	Yes	Yes	Yes
Surprise necessary?	Yes	Yes	Yes	Yes
Enabling capabilities available?	Depends on target location	Likely yes	Not available	Depends on target location
Alternatives available?	Yes	Likely yes	Not available	Likely no
Political enabling capabilities?	Yes, unless widespread collateral damage, etc.	Nearly indisputable evidence of WMD required	War	War
Conclusion	Not likely	Case-by-case	Likely	Likely

Conclusions

With the introduction of any significant new military capability, a doctrine for use should be defined and understood. The proposed criteria and four scenarios illustrate a possible method for assessing when to use an HGV. Although HGV targeting initially may be limited, e.g., A2/AD and ASAT targets, the method can be applied to future consideration of additional scenarios that might benefit from the HGV's unique combination of speed, range, and maneuverability.